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Research Paper

AN OVERVIEW OF THE METHODOLOGIES USED IN THE OPTIMIZATION PROCESSES IN SHEET METAL BLANKING

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The study shows the different methodologies used for the prediction of the optimum parameters involved in the sheet metal blanking process and optimization of these parameters. The different parameters that control the output of the process have been studied in detail and their effect on the quality of the blanked material is analyzed using different methodologies. The outcome of the study verifies the effectiveness of each methodology used for the optimization of the parameters.

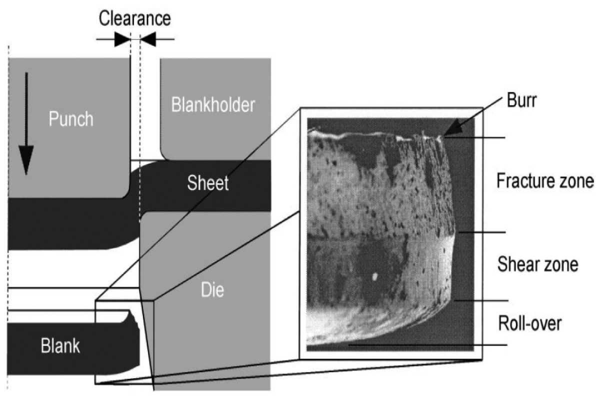
Keywords: Blanking process, Optimization, Burr height, Effectiveness

INTRODUCTION

Blanking is a common technique in high volume production. Since the beginning of this century, researchers have been analyzing the blanking process. Blanking experiments on either planar or axisymmetric configurations have led to empirical guidelines for process variables such as punch and die radius, speed and clearance. Nevertheless, the blanking process is not yet fully understood.

One major difficulty in the numerical analysis is the accurate description of ductile fracture Initiation, which greatly determines the product shape (Figure 1).

Figure 1: Blanking Process



The physical background for ductile fracture in metals is known to be the initiation, growth and coalescence of voids. Voids can initiate

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at inclusions, secondary phase particles or at dislocation pile-ups. Broken showed with numerical simulations that even under large hydrostatic pressures, voids can initiate at inclusions in shear deformation. Growth and coalescence of voids are driven by plastic deformation. Consequently, in the modeling of ductile fracture initiation, the deformation history is required.

In this paper, the classes of local ductile fracture criteria that incorporate the stress and strain history are applied for the prediction of ductile fracture initiation. They can be written in a general form as an integral over equivalent plastic strain up to fracture of a certain function of the actual stress state reaching a threshold value.

Where $f(s)$ can be interpreted as a function of the invariants of the Cauchy stress tensor s: $f(J_1, J_2$ and $J_3)$. If the integral on the left-hand side reaches the critical value C during the process, ductile fracture is supposed to initiate. In the blanking process, this initiation determines the height of the shear zone (Figure 1) and thus the shape of the blanked edge. In the formulations for the different criteria, some parameters that influence ductile fracture are expected to appear: plastic strain and triaxiality (triaxiality is defined as hydrostatic stress divided by equivalent Von Misses stress: $sh = s$). It is well known that hydrostatic pressure postpones ductile fracture initiation which is generally rationalized by the effect of this stress state on void initiation and void growth. Therefore, triaxiality is often represented in $f(s)$. Large plastic strains permit voids to grow and coalesce. This justifies the integration over plastic strain.

In the formulation of a model, C is generally regarded as a material constant. One has to perform an experiment to determine C and then it should be possible to use the characterized criterion in any desired application, the criterion ought to be valid for both the characterization experiment and the application. Unfortunately, there were no examples found in the literature where the critical value C is determined under a loading condition other than that of the actual application. In other words, existing ductile fracture criteria are only successful when they are both characterized and applied under similar loading conditions. This suggests that some information of the loading path is represented by the parameter C.

OPTIMIZATION

The processes of optimization of the parameters involve the thorough study of the desired output, which may be one of the following:

- Total cost of producing a component.
- Increasing the quality of the product.
- Reduction in in-process time of the component, etc.

In this process the operator may be desired to minimize or maximize the objective function.

The different factors that affect the output of the process of sheet metal blanking are; blank holder force, clearance, thickness, material, friction, tool geometry, blank layout, speed or stroke rate, punch die alignment. Out of these parameters first four are controllable and other are noise factors.

METHODOLOGIES

Design of Experiments

Designed experiments are a systematic approach to optimising process performance, they are also used for knowledge acquisition. Traditionally, the setting of a single factor is changed at a time until the response is improved. This one-factor-at-a-time approach is inefficient because no measures of interactions between the factors are available, and because the accuracy of the effect estimates is usually poor.

Finite Element Method

Numerical simulation of the problems associated with sheet metal forming using the Finite Element Method (FEM) can help design the process by reduc-ing the number of trial steps. Although process mod-elling by FEM simulation is already used in industry in a wide variety of forming operations, no commer-cially available FEM code is capable of simulating, with the required degree of precision, the blanking process and fracture formation.

Neural Network Analysis

The networks are employed as numerical devices for substituting the finite element code needed for the optimum clearance prediction of the sheared part. Since the main material variable describing the fracture initiation and propagation conditions is the strain at rupture (Faura *et al.*, 1998; Fang *et al.*, 2001; Maiti *et al.*, 2001; and Ridha, 2005), the input data for the artificial neural network is the material elongation A% and the output data is the optimum clearance.

Genetics Algorithm

In a genetic algorithm, a population of candidate solutions (called individuals, creatures, or phenotypes) to an optimization problem is evolved toward better solutions. Each candidate solution has a set of properties (its chromosomes or genotype) which can be mutated and altered; traditionally, solutions are represented in binary as strings of 0*s* and 1*s*, but other encodings are also possible.

The evolution usually starts from a population of randomly generated individuals and happens in generations. In each generation, the fitness of every individual in the population is evaluated, the more fit individuals are stochastically selected from the current population, and each individual's genome is modified (recombined and possibly randomly mutated) to form a new population. The new population is then used in the next iteration of the algorithm. Commonly, the algorithm terminates when either a maximum number of generations has been produced, or a satisfactory fitness level has been reached for the population.

A standard representation of each candidate solution is as an array of bits (Faura *et al.*, 1998). Arrays of other types and structures can be used in essentially the same way. The main property that makes these genetic representations convenient is that their parts are easily aligned due to their fixed size, which facilitates simple crossover operations. Variable length representations may also be used, but crossover implementation is more complex in this case. Tree-like representations are explored in genetic programming and graph-form representations are explored in evolutionary programming; a mix of both linear chromosomes and trees is explored in gene expression programming.

Once the genetic representation and the fitness function are defined, a GA proceeds to initialize a population of solutions and then to improve it through repetitive application of the mutation, crossover, inversion and selection operators.

LITERATURE SURVEY

The process of identifying process influencing parameters of blanking process includes an exhaustive literature review of the factors that have been suggested by various authors. Literature review was performed by collecting articles from various journals, and various popular research related sites viz., Science Direct, IEEE, Emerald, Springer Link and various free articles from internet. Literature from journal papers and conference studied for various press tool works parameters optimization are reviewed.

Hambli (2002), presents an experimental investigation into the blanking process was carried out using tools with four different wear states (wear radius 0.01, 0.06, 0.012, 0.2 mm) and four different clearances (5%, 10%, 15%, 20%). The aim was to study the effects of the interaction between the clearance, the wear state of the tool and the sheet metal thickness on the evolution of the blanking force and the geometry of the sheared profile. He used designed of experiment method for model and analysis the relationships that describe process variations. The interactions between controllable factors (clearance) and noise factors (wear and thickness) are useful in reducing the influence of the noise factors and thereby making the process more robust against variations in tool wear and sheet thickness. The process signatures indicate that the maximum shearing force, the fracture angle and the fractured surface depth are influenced by the material condition as well as the geometric characteristics of the tools and their configurations. The analysis of the tool wear influence allows for the monitoring of the blanking operation and so the parts quality variations during the forming process may be predicted. This investigation shows that, in order to minimise the blanking force, the clearance should be set at 10%, however, to minimise the fracture angle and the fracture depth, it is preferable to set the clearance at 5%. When the clearance is set at 10%, the process is slightly more robust to tool wear, as far as the blanking force response is concerned. Whether clearance should be set at 5% or 10% ultimately depends on the priorities of the practitioners.

Faura *et al.* (1998) they proposed a methodology to obtain optimum punch-die clearance values for a given sheet material and thickness to be blanked, using the finite-element technique. In the present investigation, the shearing mechanism was studied by simulating the blanking operation of an AISI 304 sheet. Simulation used the FEM program ANSYS and also the Crockroft and Latham fracture criterion. In his investigation it is assumed that clearance is optimum when the direction of crack propagation coincides with the line joining the points of crack initiation in the punch and die (diagonal line), giving cleanly blanked surfaces. To determine the optimum clearance, the diagonal angle and the angle of the direction of crack propagation for different clearances were calculated. The influence of clearance on diagonal angle and angle of the direction of crack propagation, from which it is seen that as the clearance increases, diagonal angle increases proportionally while angle of the direction of crack propagation remains nearly constant. At the point of intersection, the direction of crack propagation coincides with the diagonal line, and so the cracks emanating from the punch and die meet, resulting in a cleanly blanked surface. Hence, this value of clearance is taken as the optimum clearance. The optimum clearance for the values of the parameters used in this work is between 11 and 12%. It is observed that punch penetration increases as the c/t ratio increases.

Hambli *et al.* (2003) elaborates blanking process and structure of the blanked surfaces are influenced by both the tooling (clearance and tool geometry) and properties of the work piece material (blank thickness, mechanical properties, microstructure, etc.). Therefore, for a given material, the clearance and tool geometry are the most important parameters. They use simulation of an axisymmetric blanking operation with ABAQUS-explicit software for a given sheet material. A damage model of the Lemaitre type is used in order to describe crack initiation and propagation into the sheet. They use four materials for testing with four different elongation (30%, 47%, 58%, and 65%). They show that the optimum clearance decreases as the material elongation increases. The results of the proposed experimental investigation show that there is no universal optimal clearance value. Whether clearance should be set at 5% or 10% ultimately depends on the priorities of the practitioners; said by Emad and Ibrahim.

Emad and Ibrahim (2008), Represents a model investigates the effect of potential parameters influencing the blanking process and their interactions. Finite Element Method (FEM) and Design of Experiments (DOE) approach are used in order to achieve the intended model objectives. The combination of both techniques is proposed to result in a reduction of the necessary experimental cost and effort in addition to getting a higher level of verification. It can be stated that the Finite Element Method coupled with Design of Experiments approach provide a good contribution towards the optimization of sheet metal blanking process. They use Design of Experiments (DOE) technique by selecting the experimental levels for each selected factor, i.e., the clearance to be in five levels (5%, 10%, 15%, 20%, 25%) of the sheet metal thickness, blank holder force to be in two levels (0, 3000 N) and sheet metal thickness to be in four levels (0.5 mm, 0.6 mm, 0.7 mm, 0.8 mm). Perform a factorial experimental design in order to take high-level interactions. Develop a Finite Element Model (FEM) that represents the existing process in order to evaluate the quality of the inputs. Compare the two techniques (FEM and DOE) and analyze the results to get the proposed optimal set of parameters. Simulations are conducted on commercial FEM software package ABAQUS/ Explicit. in their article, they show that, in order to minimize the burrs height, the clearance should be set at about 5% with almost no blank holder force.

Maiti *et al.* (2001) they evaluate the influence of tool clearance, friction, sheet thickness, punch/die size and blanking layout on the sheet deformation for thin M S sheet.

The punch load variation with tool travel and stress distribution in the sheet has been obtained. The results indicate that a reduction in the tool clearance increases the blanking load. The blanking load increases with an increase in the coefficient of friction. These observations are very similar to the case of blanking of component of large size. Further, these effects are very similar in the case of both single and double blanking. An interblanking site distance of about twice the sheet thickness is good to reduce the thinning of sheet at the intermediate regions between the two blanking sites. The FEM analysis has been done using ANSYS package. The blanking load increases with a reduction in the tool clearance in the case of both single and double blanking. The blanking load increases with an increase in the coefficient of friction at the tool sheet interfaces.

Ridha (2005) presents an industrial software called BLANKSOFT dedicated to sheet metal blanking processes optimization. The code allows for the prediction of the geometry of the sheared profile, the mechanical state of the sheared zone, the burr height, the force-penetration curve, and the wear evolution of the punch versus the number of the blanking cycles. The approach is based on an original theoretical investigation formulated from plasticity theories. This program is designed by considering several factors, such as material and geometry of product as well as the wear state of the tool. The numerical results obtained by the proposed programs were compared with experimental ones to verify the validity of the proposed software.

Ridha (2005) describes a methodology using the finite element method and neural network simulation in order to predict the optimum punch-die clearance during sheet metal blanking processes. A damage model is used in order to describe crack initiation and propagation into the sheet. The proposed approach combines predictive finite element and neural network modeling of the leading blanking parameters.

Ridha (2005), Fabric Guerin, they develop a methodology to obtain the optimum punch-die clearance for a given sheet material by the simulation of the blanking process. A damage model of type Lemaitre is used in order to describe crack initiation and propagation into the sheet. The proposed approach combines predictive finite element and neural network modeling of the leading blanking parameters. The blanking process and the structure of the blanked surface are influenced by both the tooling (clearance and the tool geometry) and the properties of the work piece material (blank thickness, mechanical properties, microstructure, etc.). They show that the optimum value of clearance decreases with increasing material ductility.

They have developed a methodology to obtain the optimum punch-die clearance for a given sheet material by the simulation of the blanking process. The proposed approach combined predictive finite element and neural network modeling of the leading blanking parameters.

Fang *et al.* (2002) investigated the punch-die clearance values for a given sheet material and the thickness are optimized by using a finite element technique in which the shearing mechanism was studied by simulating the blanking operation. The clearance impact on the blanking processes has consumed a significant amount of research. This concern about the clearance factor is because the structure of the blanked surfaces is influenced by both the tooling (clearance and tool geometry) and the properties of the work piece material (blank thickness, mechanical properties, microstructure, etc.). The selection of the clearance influences the life of the die or punch, the blanking force, the unloading force and the dimensional precision.

Maiti *et al.* (2001) analyzed the blanking of thin sheet of mild steel using an elastic plastic finite element analysis based on the incremental theory of plasticity. The study has helped to evaluate the influence of tool clearance, friction, sheet thickness, punch/die size, and blanking layout on the sheet deformation.

A review of the literature on the blanking process shows that while a large number of analytical techniques have been used to study the process, the amount of theoretical and practical work done is relatively insufficient and thus further investigation is still needed.

RESULTS

From the above study conducted we can conclude that, though there are many different methodologies adopted, the decision to specify the most effective methodology is difficult.

- Design of experiments technique helps to find the most effective parameter leading towards optimal combination of parameters setting.
- The results obtained by finite element simulation only gives the best tool setting for the optimum process output.
- In neural network analysis we have to train a network using artificial intelligence which is an costly and time consuming procedure.
- The genetics algorithm technique consists of a series of mathematical formulae's and algorithms to come out with an optimum results.

CONCLUSION

The different methodologies adopted consistently prove the optimization of the blanking process with varied effectiveness.

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